December 10, 2020

VIA ECFS

Marlene H. Dortch
Secretary
Federal Communications Commission
45 L Street, NE
Washington, DC 20554

Re: *Ex Parte* Notice
IB Docket No. 18-315; CG Docket Nos. RM-11855 and RM-11861

Dear Ms. Dortch:

On Tuesday, December 8, 2020, representatives of Kuiper Systems LLC, a wholly owned subsidiary of Amazon.com Services LLC ("Amazon"), met via telephone with staff from the International Bureau regarding the above-referenced proceedings. A list of meeting participants is attached.[1]

Amazon presented the study from its reply comments in the proceeding on non-geostationary orbit ("NGSO") earth stations in motion ("ESIM"). Amazon explained that ESIM communicating with non-geostationary orbit ("NGSO") fixed-satellite service ("FSS") systems in the 28.35-28.6 GHz band will not cause harmful interference to terrestrial services operating in the 27.5-28.35 GHz band.[2]

Upper microwave flexible use service ("UMFUS") advocates have claimed NGSO ESIM deployments in the 28.35-28.6 GHz band could uniquely impair UMFUS operations in the adjacent

[1] *See* Attachment A; *see also* Attachment B (appending copy of presentation).
[2] *See Facilitating the Communications of Earth Stations in Motion with Non-Geostationary Orbit Space Stations*, Further Notice of Proposed Rulemaking et al., 35 FCC Rcd 5137 (2020); *see e.g.*, Reply Comments of Amazon, IB Docket No. 18-315 (filed Sept. 22, 2020) ("Amazon Reply Comments"); *see also, e.g.*, Reply Comments of Satellite Industry Association, IB Docket No. 18-315 (filed Sept. 22, 2020); Reply Comments of Kepler, IB Docket No. 18-315 (filed Sept. 21, 2020); Comments of Viasat, IB Docket No. 18-315 (filed Aug. 24, 2020).

band,[3] as compared to other FSS services already authorized in the 28.35-28.6 GHz band.[4] But the terrestrial community has failed to support the assertion that NGSO ESIM pose a distinct threat of harmful interference.[5]

Another study filed after the comment deadline purported to explain the interference risk, but only considered a worst-case geometric alignment of UMFUS and NGSO ESIM[6] in a worst-case environment.[7] That study failed to document how often the worst-case alignment would occur or how long the worst-case alignment would persist, nor did the study quantify the effect of the worst case alignment on UMFUS users. In contrast, Amazon's study demonstrates that it is highly unlikely that NGSO ESIM operations will affect UMFUS operations under real world-conditions. Amazon's study also shows how current out-of-band emissions ("OOBE") limits in section 25.202(f) provide adequate protection to UMFUS operations in the adjacent band[8] and why no new regulations are necessary.

Amazon's study was based on Monte Carlo simulations using a large multi-dimensional sample size.[9] The study considered multiple factors, including: (i) the movement of the ESIM, NGSO

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[3] *See* Reply Comments of CTIA, IB Docket No. 18-315, at 6 (filed Sept. 22, 2020) ("NGSO ESIMs pose unique interference risks to adjacent band terrestrial operations[.]"); Comments of Verizon and U.S. Cellular ("UMFUS Interests"), IB Docket No. 18-315, at 7 (filed Aug. 24, 2020) ("NGSO ESIMs operating in the 28.35-28.6 GHz band pose unique interference risks to adjacent band terrestrial operations primarily due to their mobility.").

[4] *See* Reply Comments of Global Mobile Suppliers Association, IB Docket No. 18-315 (filed Sept. 23, 2020) ("GSA Reply Comments"); Reply Comments of UMFUS Interests, IB Docket No. 18-315 (filed Sept. 22, 2020).

[5] Initial claims of a potential for interference between these adjacent-band services appeared in four drawings of worst-case interference scenarios. *See* Letter from Daudeline Meme, Verizon, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 18-315, at Attachment (filed May 4, 2020).

[6] This NGSO ESIM study assumed maximum power levels under section 25.204(b), for example. *See* 47 C.F.R. § 25.204(b). However, this operational scheme remains improbable for an ESIM for many practical reasons, including the requirement for Part 25 equipment to comply with the Commission's radiofrequency exposure limits. An earth station transmitting at that power level would require a separation distance from the general population that would render it unusable on a land-ESIM such as a bus in a densely populated urban environment.

[7] *See, e.g.*, GSA Reply Comments at Annex 2. The GSA Reply Comments were filed Sept. 23, 2020, after the Sept. 22, 2020 deadline. *See Earth Stations in Motion*, 85 FR 44818 (2020).

[8] *See* 47 C.F.R. § 25.202(f).

[9] The Commission routinely relies on probabilistic analyses when addressing spectrum-sharing concerns. *See, e.g., Unlicensed Use of the 6 GHz Band et al.*, Report et al., 35 FCC Rcd 3852 ¶¶ 135, 230 (2020) (asserting that (i) spectrum-sharing analysis between fixed microwave and unlicensed services should "take a statistical approach such as in Monte Carlo simulations so as to probabilistically account for many intertwined phenomena" and (ii) resulting spectrum-sharing rules weighed not only the probabilistic technical analysis but also the economic costs if harmful interference occurs and substantial economic benefits of making new spectrum available) ("*6 GHz Order*"); *Service Rules for Advanced Wireless Services H Block—Implementing Section 6401 of*

satellites, and randomly-distributed UMFUS users positioned throughout a coverage area of seven UMFUS base stations, each with three sectors; (ii) base station and ESIM loading factors; and (iii) the variation of propagation fading due to clutter with an environment-appropriate representation of line-of-sight probability in conformance with 3GPP standardization. The study also assumed conservative technical parameters for NGSO ESIM and UMFUS systems.[10]

The results conclusively demonstrate the low probability that an interference event would occur and the limited practical consequences of any such event. More than 99% of UMFUS users[11] would experience no measurable service degradation whatsoever.[12] In the rare occasion an UMFUS user experiences interference from an NGSO ESIM,[13] it might experience reduction in throughput equal to one percent for the duration of alignment.[14] Such a minimal and fleeting reduction in the user experience does not justify the draconian guard band and power limits proposed by the UMFUS community, which, if imposed, would limit the viability of Ka-band NGSO ESIM services in the United States and leave valuable spectrum underutilized.[15]

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the Middle Class Tax Relief and Job Creation Act of 2012 Related to the 1915-1920 MHz and 1995-2000 MHz Bands, Report and Order, 28 FCC Rcd 9483 ¶ 23 (2013) (considering the "probabilistic nature of mobile-to-mobile interference" and holding that the Commission's rules "are not, nor could they reasonably be, designed to prevent all possible instances of interference generally") ("*H Block Order*").

[10] *See* Amazon Reply Comments at 3-6.

[11] *See id.* at 6 (finding that 99% of user locations exhibited a signal-to-noise-and-interference ratio ("SINR") degradation of "less than 0.03 dB over 99% of the time").

[12] Amazon assessed the (i) change in the uplink SINR per user and (ii) loss in channel capacity because of adjacent-band NGSO ESIMs for both a time-average and 1% time-exceedance. Among 99% of users, performance impacts in both statistics were a fractional dB/percentage that would be immeasurably small in an operational environment.

[13] In unusual cases where more than one ESIM is located in a local geographic area, those ESIMs will not be operating in the same frequency band at the same time to avoid self-interference. Taking this measure ensures that only one adjacent band ESIM will be present in an area at any given time. Other NGSO ESIM operational and design features further reduce interference potential. ESIM operators "possess strong commercial incentives to transmit into clear line-of-sight conditions" away from where receiving UMFUS base stations will operate and will efficiently share FSS uplink spectrum resources employing "time division multiple access through the time domain scheduling of uplink frames." Amazon Reply Comments at 4 and Technical Annex at 6.

[14] For at least 99% of the simulation's duration, 99.9048% of users only saw a loss in capacity of under 1% due to NGSO ESIM interference. In other words, for more than 99.9% of users, if a user expects 100 Mbps of bandwidth under normal circumstances, an interference event from an NGSO ESIM might reduce that bandwidth to 99 Mbps.

[15] Amazon's study demonstrates that the potential of harmful interference to adjacent band terrestrial users from NGSO ESIMs in dense urban environments is a remote possibility with minimal effect on the UMFUS end user experience. For ESIM deployments outside of dense urban

Amazon further explained how much of the concern about harmful interference would be mitigated, rather than exacerbated, by the continuously changing geometries created by the transient nature of both the ESIM and NGSO satellites. Where an ESIM is stationary, it is no different from a fixed NGSO FSS earth station that is already subject to the Commission's existing OOBE rules.[16]

Not all possible risks require regulatory intervention. The Commission considers both the significance and the *likelihood* of harm before it imposes new obligations on licensees.[17] In this case, both the gravity and the likelihood of the harm to UMFUS are extremely low, and the costs of imposing constraints on NGSO ESIM services or of creating fallow "guard bands" from otherwise useful spectrum are immense. The weight of the evidence, thus, provides one rational conclusion: UMFUS and adjacent-band NGSO ESIM deployments can coexist under the Commission's existing rules[18] without additional regulatory constraints on NGSO ESIM operations.[19]

During the call, Amazon also emphasized the importance of the petitions for rulemaking regarding NGSO FSS spectrum sharing under section 25.261 and NGSO FSS license modifications under section 25.117 of the Commission's rules.[20] Modernization of the NGSO regulatory framework will ensure the United States keeps pace with the new space age and will promote fairness, competition, and innovation. Amazon looks forward to continued collaboration with the Commission on these rulemakings.

Please contact me with any questions.

Respectfully submitted,

/s/ Will Lewis

Will Lewis
Corporate Counsel
Kuiper Systems LLC,
an Amazon subsidiary

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areas the potential for harmful interference is even less likely to occur. *See* Amazon Reply Comments at 4.

[16] *See* 47 C.F.R. § 25.202(f).

[17] *See, e.g.*, *6 GHz Order* ¶¶ 113, 120, 229-30; *H Block Order* ¶¶ 20-21, 23, 28.

[18] *See* 47 C.F.R. § 25.202(f).

[19] In fact, in another proceeding, the UMFUS community advocated to maintain the existing OOBE regulations for Part 25 earth stations in section 25.202(f) of the Commission's rules. *See, e.g.*, Letter from Jennifer L. Oberhausen, Director, Regulatory Affairs, CTIA, to Marlene H. Dortch, Secretary, FCC, at 3 (filed Nov. 11, 2020) ("CTIA strongly supports the draft decision not to adopt the proposed modifications to Section 25.202(f).").

[20] *See* 47 C.F.R. §§ 25.117, 25.261; *see also* CG Docket Nos. RM-11855 and RM-11861.

Attachment A – Meeting Participants

International Bureau

Karl Kensinger
Cindy Spiers
Merissa Velez

Amazon

Aspa Paroutsas
James Boughton
Kalpak Gude
Mariah Shuman
Will Lewis

Attachment B – Presentation

amazon | project kuiper

IB Docket No. 18-135

FNPRM asked whether typical ESIMs operations meeting the out-of-band emission ("OOBE") limits of §25.202(f) produce interference above acceptable levels.

Amazon's NGSO ESIM Study shows NGSO ESIM potential interference does not rise to the level of harmful interference because any potential interference events will be **extremely rare** and **inconsequential.**

Existing OOBE limits will protect UMFUS receivers:

i. UMFUS radios are not receiving at all times & NGSO ESIMs do not transmit at all times

ii. Differences in deployment density between ESIMs and UMFUS base stations also mitigate potential interference

UMFUS Interests

- Have not demonstrated that NGSO ESIMs pose unique interference risk to UMFUS operations.
  - Only four drawings of potential IX cases initially submitted
  - Further analysis from UMFUS stakeholders does not address:
    - how often interference would occur
    - how long interference events would last
    - the practical consequence of theoretical interference cases
- Failed to make the case that UMFUS will suffer greater risk of harmful interference from NGSO ESIMs than blanket-licensed earth stations and GSO ESIMs already authorized and operating in the band.

Amazon's Technical Study
Rationale for Monte Carlo Simulation

i. The interference environment is highly dynamic.
   i. NGSO ESIM are inherently mobile and thus change position over time
   ii. NGSO ESIM track moving satellites with connections that are subject to periodic handovers by design
   iii. UMFUS base stations offer service to individual spatially-distributed users through a combination of channelization and dynamic beamforming
   iv. UMFUS systems are generally self-interference limited by design due to a combination of high station density and reuse-1 cellular channelization
   v. Terrestrial radio channels are subject to fading due to clutter

ii. Due to such interference variability, consideration of a worst-case geometry coupled with a worst-case environment is non-representative of any practical interference risk.

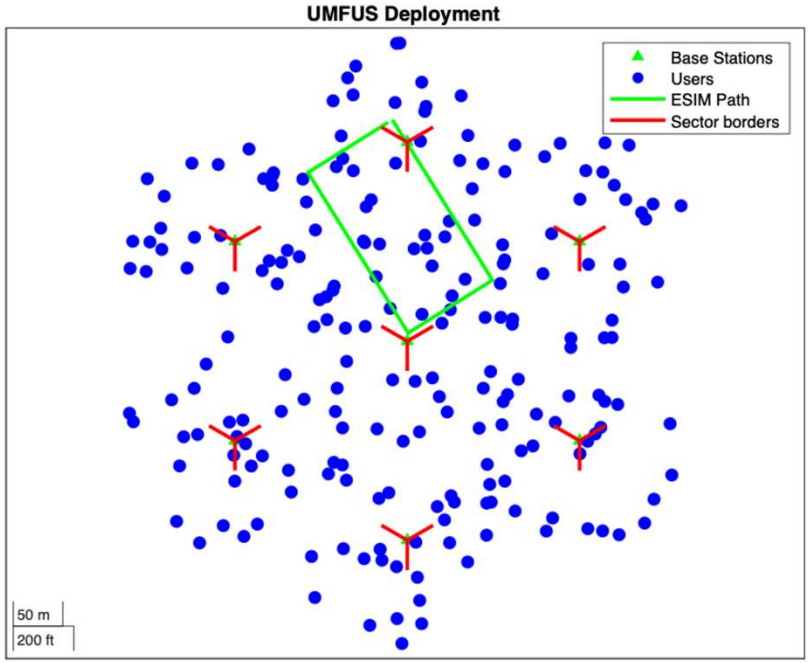
iii. A series of simulations over a large multi-dimensional sample size can relate the computed interference levels with their respective level of probability.

iv. Such methodologies as they apply to 5G terrestrial networks are well documented in the 3rd Generation Partnership Project (3GPP) standardization and the International Telecommunication Union (ITU).

Simulation Methodology

Amazon designed a study methodology to capture the dynamics of a worst-case interference environment (e.g. dense urban environment):

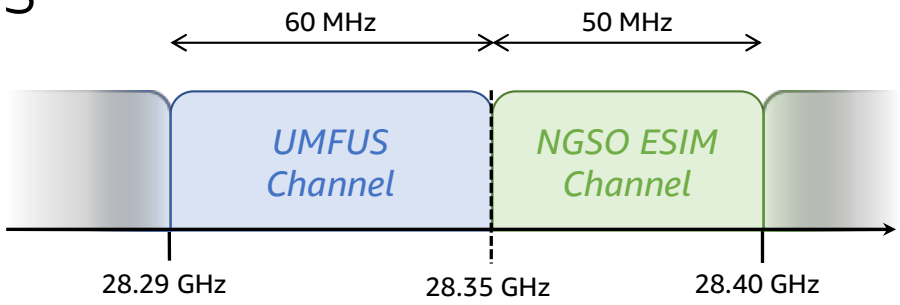
- Independent trials of a time domain simulation are performed over a simulated 24-hour period to appropriately capture the dynamics of the Kuiper satellite constellation
- An ESIM interferer travels along the same path within the UMFUS deployment for the entire duration of the simulation
- Each trial considers a random sampling of UMFUS user locations within the coverage area of the deployment in accordance with 3GPP standardization
- To assess the degradation of UMFUS service as a result of NGSO ESIM operations, the simulation considers the offered UMFUS network capacity on a per-user basis both with and without the presence of ESIM interference



Simulation snapshot: The UMFUS deployment consists of a hexagonal arrangement of 7x3 sector base stations in a dense urban environment (Seattle). Users are randomly distributed in each sector's respective coverage area.

NGSO ESIM Characteristics

Parameter	Value	Units
Uplink Center Frequency	28.375	GHz
Channel Bandwidth	50	MHz
Duplex Configuration	Frequency Division Duplex (FDD)	
Multi-Access Mechanism	FDMA and TDMA	
Total Radiated Power	5.9	dBW
Duty Cycle	50	percent
Antenna Height	2	meters
Antenna Pattern	ITU-R S.465	
Antenna Gain	31	dBi
Antenna Beamwidth	5.6	degrees
Minimum Elevation Angle	39	degrees
OOBE Limits	47 C.F.R. § 25.202(f) ITU-R SM.1541	



The NGSO ESIM technical parameters used in the simulation are conservative:

- Uplink channel occupies spectrum directly adjacent to the UMFUS deployment (see figure above)
- OOBE levels are assumed to reach up to the applicable regulatory limits
- Maximum transmission power applied throughout the simulation
- ESIM antenna pattern follows ITU envelope (worst case off-axis gain)
- Transmit duty cycle reflects a persistent high uplink data rate application (e.g. large file uploads, video sharing, etc.) throughout the entire 24 hours of the simulation

UMFUS Deployment Characteristics

- The UMFUS deployment assumptions reflect a realistic worst-case urban environment:
  - Base stations and users are in worst-case proximity to potential land-based NGSO ESIM operations.
  - Base stations modeled in a dense urban environment have lower typical beam directivity (i.e. fewer antenna elements) relative to other cellular layouts in populated areas.
- Base stations are arranged in a 3-sector macro cell arrangement for providing seamless coverage to distributed users in the deployment area
- A narrow UMFUS channel bandwidth assumption results in a higher ratio of ESIM OOBE across the channel

Parameter	Value	Units
Center Frequency	28.32	GHz
Channel Bandwidth	60	MHz
Duplex Configuration	Time Division Duplex (TDD)	
TDD Activity Factor	80 (downlink)	percent
Number of Sectors per Base Station	3	
Inter-Site Distance	200	meters
Adjacent Channel Selectivity	25	dB
Active Uplink Users per Cell	10	
User Locations	Random; uniformly throughout coverage area	
Percentage of Outdoor Antennas	100	percent

UMFUS Active Antenna Systems

- Electronically steerable advanced antenna systems (AAS) enables UMFUS towers to provide service to many users at once while affording a high degree of isolation from both internal and external interference sources.
- AAS modeling in the simulation conforms to Section 5 of ITU-R M.2101-0 Annex 1 and 3GPP TR 38.901
- User antenna heights are randomly distributed in accordance with 3GPP TR 38.901 & 3GPP 36.873

UMFUS Base Station

Parameter	Value	Units
Antenna Type	16x16 uniform rectangular array	
Element Gain	8	dBi
Antenna Height	10	meters
Antenna Down Tilt	10	degrees
Noise Figure	7	dB

UMFUS User

Parameter	Value	Units
Antenna Type	8x8 uniform rectangular array	
Element Gain	5	dBi
Antenna Height	1.5 – 22.5	meters
Maximum Uplink Power	23	dBm

Link Power Dynamics in UMFUS Network

Modeling of uplink power dynamics is essential to achieving accurate results:

- ULPC in UMFUS systems mitigates the ‘near-far’ problem encountered in high density cellular terrestrial networks by achieving a proper balance between base station received signal levels and intra-system interference from neighboring cells
- Interference simulation accurately models the uplink power control (ULPC) algorithm in accordance with TR 38.213

Study focus is on the impact of ESIM interference in the uplink direction, as the downlink direction is substantially better equipped to overcome fading:

- User uplink power is limited by power control and hardware constraints, which results in lower link margins that are more susceptible to external interference
- Moreover, maximum UMFUS base station authorized power limits in the 28 GHz bands is 75 dBm/100 MHz, which is 26.7 dB higher in power density than the user maximum power levels simulated in accordance 3GPP.

Interference Metric 1: Loss in UMFUS Uplink SINR

The results in the following slide show statistics that account for the change in per-user UMFUS signal to noise and interference ratio (SINR) due to ESIM interference.

This metric is computed as follows:

$$SINR_{i,Loss}(\text{dB}) = 10\log_{10}\left(\frac{SINR_{i,Before}}{SINR_{i,After}}\right)$$

where

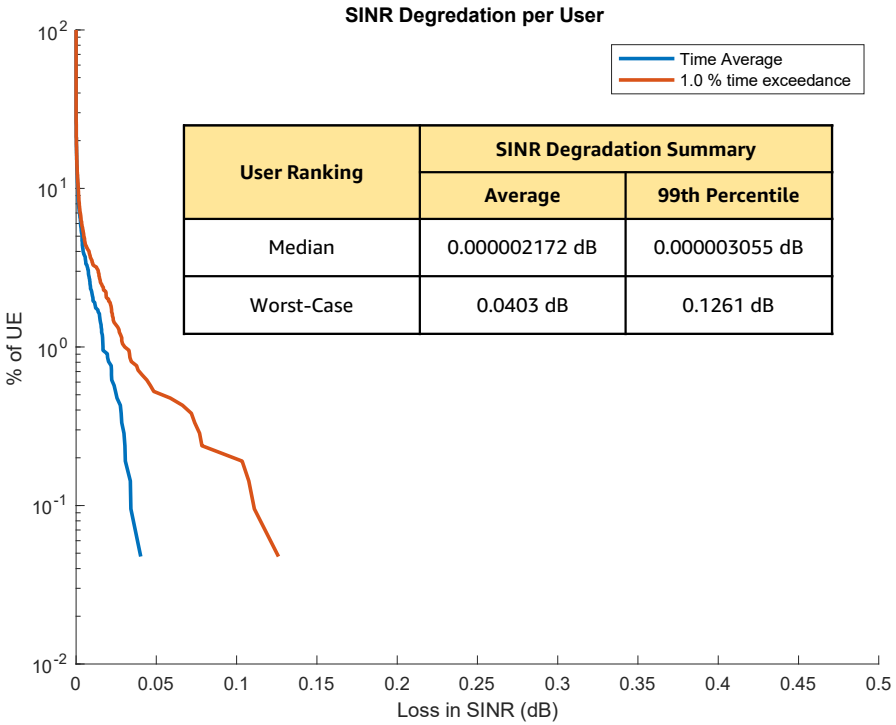
$$SINR_{i,Before} = \frac{S_{i,UMFUS}}{N_{UMFUS} + I_{i,UMFUS}}$$

$$SINR_{i,After} = \frac{S_{i,UMFUS}}{N_{UMFUS} + I_{i,UMFUS} + I_{i,ESIM}}$$

With the exception of receiver thermal noise, every other variable is time-varying due to the dynamics of the interference environment.

Parameter	Definition	Units
$SINR_{i,Loss}$	Loss in SINR for the ith user due to NGSO ESIM	-
$SINR_{i,Before}$	SINR computed for the ith user without the presence of ESIM interference	-
$SINR_{i,After}$	SINR computed for the ith user with the addition of ESIM interference	-
$S_{i,UMFUS}$	Received signal power at UMFUS base station from the ith UMFUS user	watts
N_{UMFUS}	Thermal noise power of UMFUS base station receiver	watts
$I_{i,UMFUS}$	Interference power from UMFUS operations in neighboring cells computed for ith UMFUS user channel	watts
$I_{i,ESIM}$	Interference power from adjacent-channel ESIM operations computed for ith UMFUS user channel	watts

Simulation Results: Loss in UMFUS Uplink SINR



User Ranking	SINR Degradation Summary	
	Average	99th Percentile
Median	0.000002172 dB	0.000003055 dB
Worst-Case	0.0403 dB	0.1261 dB

The chart indicates the statistical spread across UMFUS users of uplink SINR degradation. Averages and 99th percentiles are recorded for each UMFUS user across all their respective samples in the time-domain.

Out of 4,200 UMFUS users with unique locations:

- Typical users see an average SINR degradation of under 3.1 millionths of a dB due to NGSO ESIM interference for at least 99% of the duration of the simulation, far below what can practically be measured in an operational environment
- 96.6% of users saw a loss in SINR of under a hundredth of a dB due to NGSO ESIM interference for at least 99% of the duration of the simulation

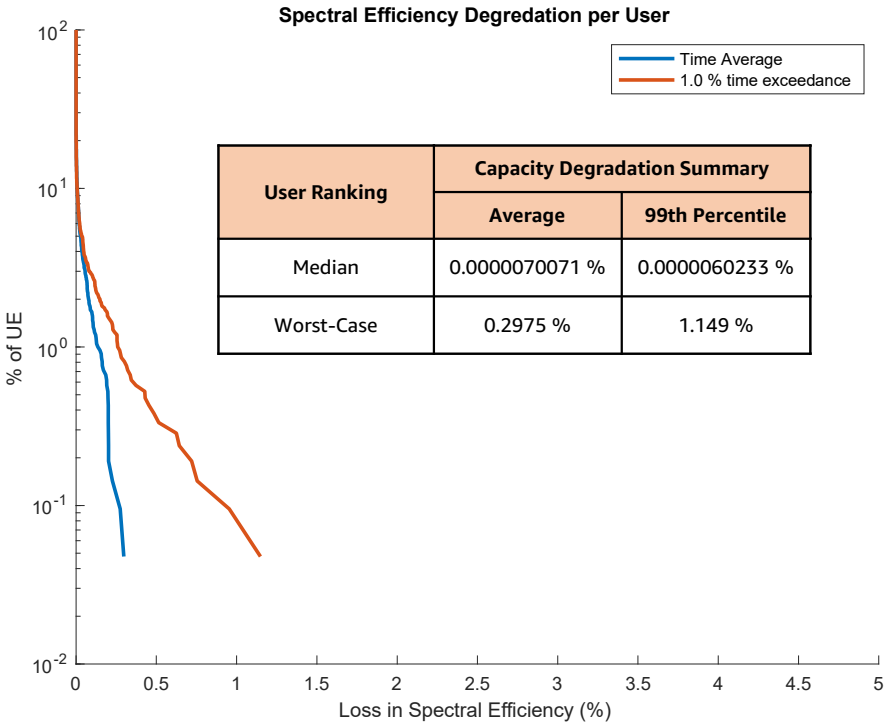
Interference Metric 2: Loss in UMFUS Uplink SINR

The before and after SINR metrics computed in the previous slides can be used to estimate the loss in channel capacity due to NGSO ESIM operations by applying the capacity equations in 3GPP TR 38.303:

$$C_{i,Loss}(\%) = \frac{S_{i,Before} - S_{i,After}}{S_{i,Before}}$$

Parameter	Definition	Units
$C_{i,Loss}$	Loss in channel capacity for the ith user due to NGSO ESIM	%
$S_{i,Before}$	Spectral efficiency computed for the ith user without the presence of ESIM interference	bits/sec/Hz
$S_{i,After}$	Spectral efficiency computed for the ith user with the addition of ESIM interference	bits/sec/Hz

Simulation Results: Loss in UMFUS Uplink Capacity



User Ranking	Capacity Degradation Summary	
	Average	99th Percentile
Median	0.0000070071 %	0.0000060233 %
Worst-Case	0.2975 %	1.149 %

The chart indicates the statistical spread across UMFUS users of uplink capacity degradation. Averages and 99th percentiles are recorded for each UMFUS user across all their respective samples in the time-domain.

Out of 4,200 UMFUS users with unique locations:

- Typical UMFUS users are shown to retain 99.999992% of their original capacity after the introduction of NGSO ESIM interference
- 99.9048% of users saw a loss in capacity of under 1% due to NGSO ESIM interference for at least 99% of the duration of the simulation

Conclusion

- Amazon's extensive simulations of NGSO ESIM within UMFUS deployments applied conservative assumptions for both interferer and victim systems
- Results indicate that harmful interference from adjacent channel NGSO ESIM to UMFUS operations is *inconsequential.*
- Other factors further reduce the possibility of harmful interference.
  - The ESIM's actual OOBE is unlikely to be exactly at the FCC/ITU limits, and OOBE will likely roll off more than was modeled.
  - Similarly, the actual ESIM antenna pattern is unlikely to exactly match the ITU envelope, and therefore the off-axis gain in a real-world ESIM deployment will likely be lower than assumed.
- Current OOBE power density limits appropriately protect UMFUS licensees from potential adjacent band ESIM interference.
- Study results further indicate that UMFUS licensees remain protected without the introduction of an unnecessary guard band on the boundary between the terrestrial and satellite services.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